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Performance Enhancement of DFIG based WECS during Voltage Fluctuations using ANN Controller

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Abstract:
The demand for wind generation in today’s grid is increasing its proposition in total electricity generated. To enhance the dependableness of the ability system a completely unique fault-tolerant configuration for wind energy conversion systems (WECSs) throughout totally different varieties of grid faults is planned. The planned configuration is developed by commutation the standard six-switch grid-side device (GSC) of DFIG (Doubly Fed Induction Generator) with a nine-switch device. The nine-switch device provides six output terminals. The primary 3 output terminals connected to the grid and therefore the next 3 output terminals are connected to neutral aspect of the mechanical device windings to supply pre-fault voltage. the substitute NEURAL NETWORK (ANN) primarily based PI management for wind energy conversion systems (WECSs) is developed , that achieves improved fault ride-through capability throughout LLLG faults. The effectiveness of the ANN management is compared thereto of a Proportional Integral (PI) controller and evaluated victimization MATLAB on a 5-MW WECS. The simulations for Doubly Fed Induction Generator are elucidated using SIMULINK/MATLAB, corresponding results and waveforms are displayed.

Index Terms: Artificial Neural Network, Fault Ride Through, Nine switch inverter, Wind Energy Conversion System.

I. INTRODUCTION

Wind energy is taken into account as associate actual degree various to the traditional and fuel energy sources like oil, gas, and coal because of their advantageous characteristics, most of the grid-connected wind turbines operate at a variable speed [2]. Since, it's to address the intermittent and seasonal variability of the wind, the doubly fed induction generator (DFIG) is employed.

Wind energy conversion systems connected to the grid should be designed to reduce the price of equipped energy making certain safe operation, acoustic emission and grid association needs. In the standard DFIG, the mechanical device windings are directly connected to the grid and therefore the rotor windings are connected tothegridthrough twelve switch consecutive connected voltage-source converters (VSCs) [5].

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The two VSCs rotor-side device (RSC), connected between the rotor and dc link and also the grid-side device (GSC), is interfaced between the grid and dc link, through inductors. The stator coil windings are interfaced on to the grid, If there's any voltage dip at the DFIG terminals ensuing from the grid fault directly affects the air-gap flux and, hence, the energy conversion method. Voltage dip induces DC element in keeping with the kind of fault. The flux elements induces high voltage within the rotor windings at double the move frequency.

The RSC cannot management these high-frequency voltages because of the modulation index limitations and thence loses its current management capabilities.

Grid faults additionally cause severe mechanical stress on the bearings and also the gear box because of force pulsation. To get Seamless FRT performance, it's necessary to stay the pre-fault voltage across the stator coil windings throughout the grid faults.

Inorder toattain seamlessFRToperation victimization minimum extra elements, the fault-tolerant configuration of DFIG employing a nine-switch device are projected. In this configuration, a 9 switch electrical converter is employed rather than six switch electrical converter to produce 2 free three-phase outputs. one amongst these three-phase outputs is connected to grid through interfacing inductors to appreciate traditional GSC operation, and the second output is connected to the neutral facet of the stator coil windings to produce series voltage compensation capability to DFIG for riding through any reasonably grid faults. An appropriate algorithmic rule for the management of a nine-switch device is developed to attain the seamless FRT operation of DFIG. Artificial intelligence are in the main used for the aim of dominant the system. The outcomes are taken on the idea of the info provided to regulate the system rather than the mathematical analysis. These intelligent techniques are wont to management the wind energy like optimum style of proportional-integral controllers for the Doubly-Fed Induction Generator (DFIG) is given in [18].

Artificial intelligence are mainly used for the purpose of controlling the system. The outcomes are taken on the basis of the database provided to control the system instead of the mathematical analysis. These intelligent techniques have been used to control the wind energy such as optimal design of proportional-integral controllers for the Doubly-Fed Induction Generator (DFIG) is presented in [18].

II. NINE-SWITCH CONVERTER CONTROL DURING LLLG FAULT MODE

During the LLLG fault condition, the GSC controller is switched to supply one third of the reactive current required. The reference reactive current for the GSC during fault (i^*_{gq})mode of operation is computed as shown below.

$$i^*_{gq} = \frac{0.3}{0.4}(0.9 - Vg) \quad \text{if } 0.5 \leq Vg \leq 0.9 \quad \text{--(1)}$$

$$i^*_{gq} = 0.3 \quad \text{if } Vg < 0.5 \quad \text{--(2)}$$

The purpose of the Nine switch converter during LLLG fault condition is to maintain the nominal voltage across the stator winding for the normal functioning of

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the RSC control. The logic high on the fault signal during fault condition activates the NSC controller. The compensating voltage ($Vdc_{,C}$) is injected by the NSC on the neutral part of the stator winding during fault condition, is computed as,

$$Vdq,c = Vdq - Vdq_{,pf}. \quad -(3)$$

To achieve perfect compensation of the voltage dip, the switching voltage drop is added to $Vdq_{,C}$ by estimating it using ANN controller which maintains the stator flux at its pre-fault value.

- PI controller as shown in fig 1 increases the maximum overshoot of the system.
- PI controller tends to make the system unstable under parameter variation.

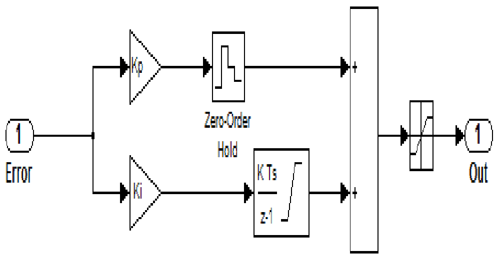

FIG.1 PI CONTROLLER

III. DESIGN OF ARTIFICIAL NEURAL NETWORK CONTROLLER

Thus to improve the performance of the wind energy system, PI controller is replaced with ANN based PI controller as shown in fig.2

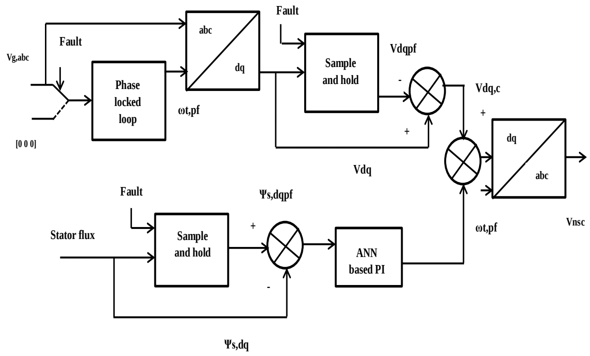

FIG.2 ANN CONTROL STRATEGY

Most Commonly used training method for feed forward Multilayer Neural Networks (MNN) is the back propagation algorithm. The purpose of a controller is to provide the desired output for any system. Since neural networks have learning and self-organizing abilities allowing them to adapt changes in data, such networks are used for control of non-linear flank wear. An artificial neural network is defined as a data processing system consisting of a large number of simple highly interconnected processing artificial neurons in an architecture inspired by the structure of the cerebral cortex of the brain. Neural networks learn by example. They are trained with known examples to acquire knowledge about a problem. Once appropriately trained, the network is put to effective use in solving unknown or untrained instances of the problem. In supervised learning, a teacher is assumed to be present during the learning process in which the network aims to minimize the error between the target (desired output) and the compared output to achieve better performance. The ANN based PI is shown in fig.3.

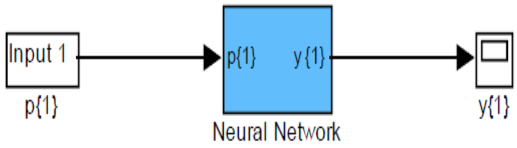

FIG. 3 ANN BASED PI CONTROLLER

When the fault is enabled, the flux linkage due to the fault is compared to the flux reference of the prefault voltage and the input samples are send to the ANN based PI controller as shown in Fig.2.The error is minimized and the performance of the system is improved by providing the prefault voltage across stator terminals.

IV. PERFORMANCE EVALUATION

A. MEAN SQUARE ERROR OF TRAINING
   1. Substitute each predictor in a training set to a network function.
   2. Determine the mean square error of approximating the desired target by the network output.

B. Mean square error of testing indicates generalization capability of a network function

MEAN SQUARE TRAINING ERROR

$$E_S(\theta) = \frac{1}{2N}\sum_{i=1}^{N}(Y[t] - F(X[t];\theta))^2$$

S = {(X[t],Y[t])}$_t$: training set

MEAN SQUARE TESTING ERROR

$$E_S, test = \frac{1}{2N}\sum_t[Y[t] - [-[X[t]/\theta]]^2$$

S_ test = {(X[t],Y[t])}

Where y[t] is the desired output.

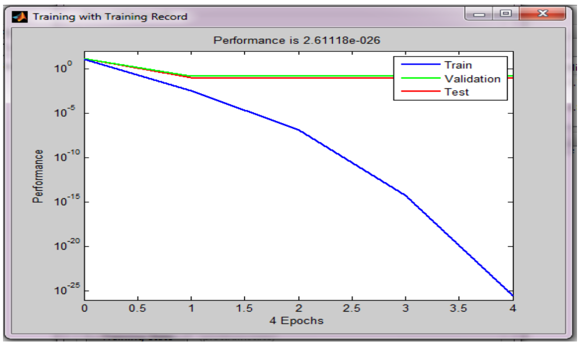

FIG. 4. PERFORMANCE PLOT

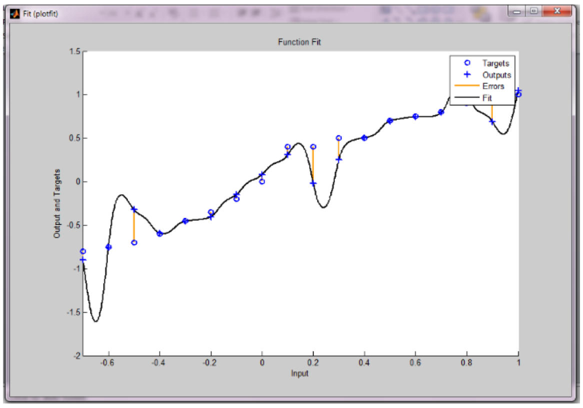

FIG. 5 FIT FUNCTION

The Function fit is shown in fig.5 in which the target is achieved by minimizing the error and the performance plot is shown in fig.4. From the above plot, the best validation performance is obtained as 2.6118e-026.

V. SIMULATION AND RESULTS

PWM is an advanced technique that utilizes dc bus voltage more effectively and generates less total harmonic distortion. PWM utilizes a chaotic changing switching frequency to spread the harmonics continuously to a wide band area so that the peak harmonics are reduced greatly.

Simulation of NSI fed DFIG based WECS with ANN controller

The pulse width modulated nine switch inverter fed DFIG based WECS during different kinds of grid faults is

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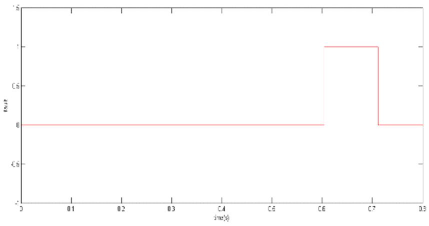
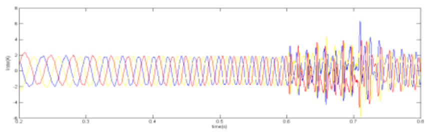
modeled and the simulation results during LLLG faults are shown.

In a six switch WECS, due to the increase in stator flux during grid fault condition, the post fault voltage results in high current in the WECS system. The replacement of the this inverter becomes complex. To overcome this, a nine switch inverter has been used to maintain the pre-fault voltage across the stator winding during grid faults.

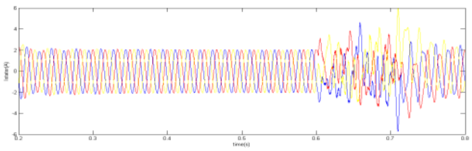
FAULT



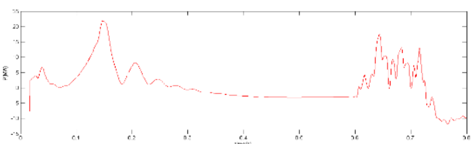
ROTOR CURRENT



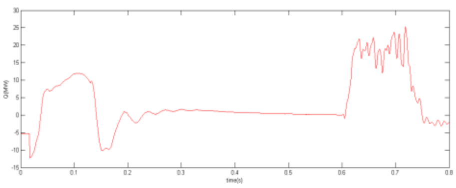
STATOR CURRENT



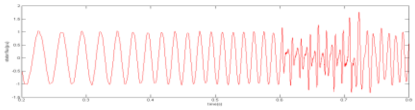
REAL POWER



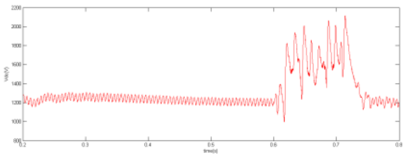
REACTIVE POWER



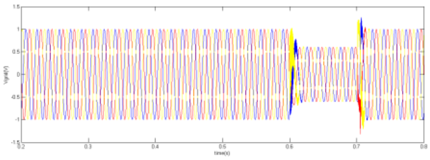
STATOR FLUX



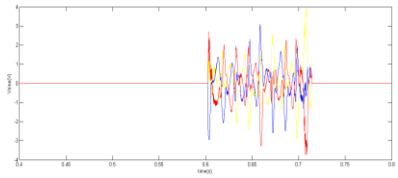
DC LINK VOLTAGE



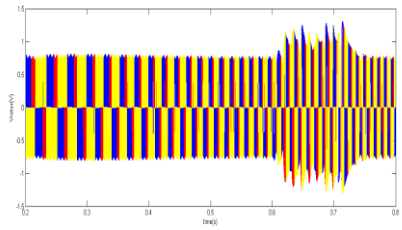
GRID VOLTAGE



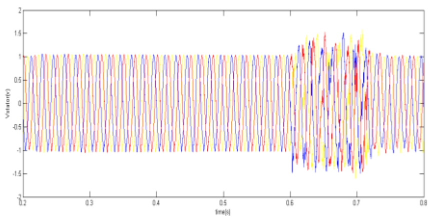
NINE SWITCH INVERTER VOLTAGE



ROTOR VOLTAGE



STATOR VOLTAGE



ROTOR SPEED

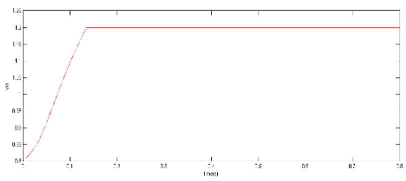


Fig 6 Simulation result of NSI fed DFIG based WECS with PI Controller during LLLG fault

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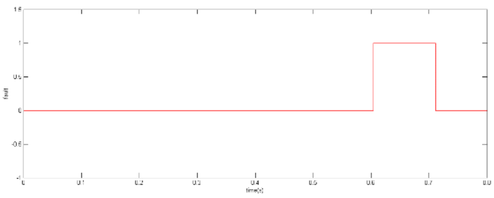
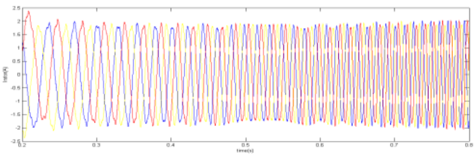
The simulation of WECS for LLLG fault with PI control is shown in fig 6. The duration of fault is 0.6 to 0.7seconds. From the above results the system is under steady state before the simulation time of 0.6 s, A LLLG fault is applied on 120 kV bus at 0.6 s, which is observed from the dip in the grid voltages. The fault signal goes high whenever fault is detected and enables the NSC With PI control which injects compensating voltage on the neutral side of the stator winding to maintain pre-fault voltage across it. The performance of NSC is to maintain the pre- fault voltage across the stator winding is shown above fig. Here stator flux vector is maintained nearly constant throughout the fault duration. The performance during the fault condition with PI control is obtained with ripples and inorder to maintain the stable fault ride through, the ANN controller is developed.

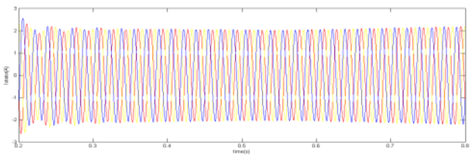
FAULT



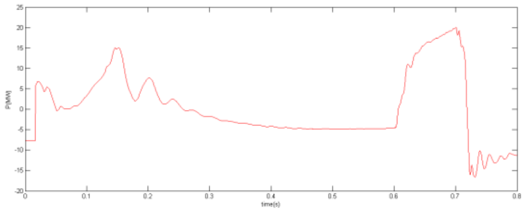
ROTOR CURRENT



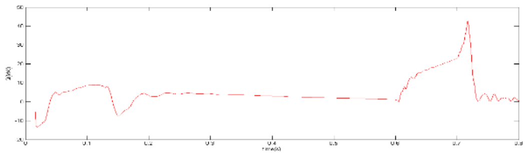
STATOR CURRENT



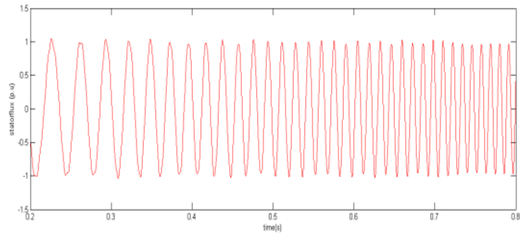
REAL POWER



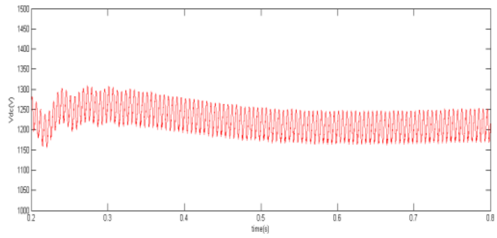
REACTIVE POWER



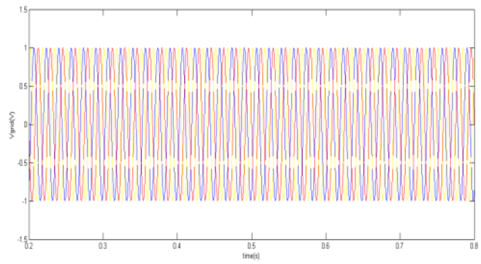
STATOR FLUX



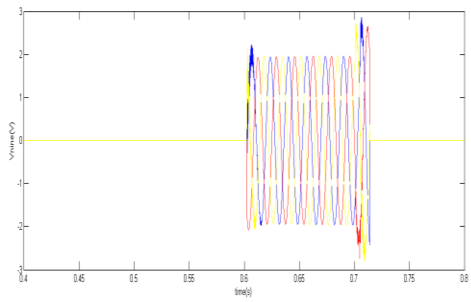
DC LINK VOLTAGE



GRID VOLTAGE



NINE SWITCH INVERTER VOLTAGE



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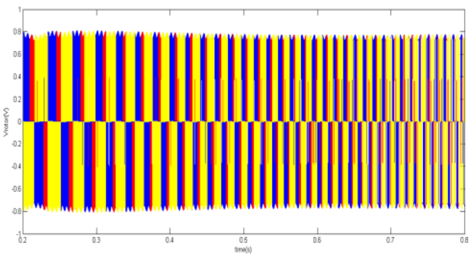
ROTOR VOLTAGE



STATOR VOLTAGE

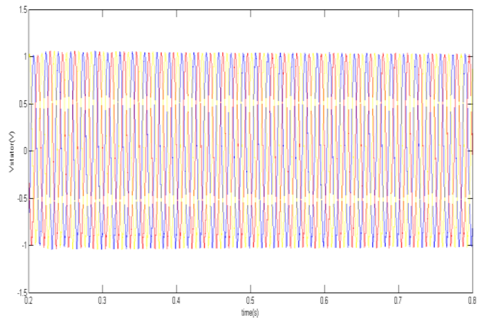
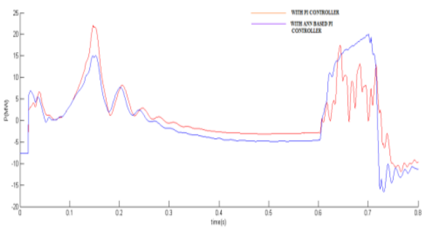


Fig 7 Simulation result of NSI fed DFIG based WECS with ANN during LLLG fault

The simulation of WECS for LLLG fault with ANN controller is shown in fig 7.The duration of fault is 0.6 to 0.7seconds. From the above results the system is under steady state before the simulation time of 0.6 s, A LLLG fault is applied on 120 kV bus at 0.6 s, which is observed from the dip in the grid voltages. The fault signal goes high whenever fault is detected and enables the NSC with ANN control which injects compensating voltage on the neutral side of the stator winding to maintain pre-fault voltage across it. The performance of NSC with ANN control in maintaining the pre- fault voltage across the stator winding is shown above fig. Here stator flux vector is maintained constant throughout the fault duration. The injection of the reactive current assigned to GSC is observed from the fig.7.

Thus the fault ride through has been established in the DFIG based WECS system by injecting the appropriate voltage through the neutral winding of the nine switch inverter fed DFIG .

REAL POWER



REACTIVE POWER

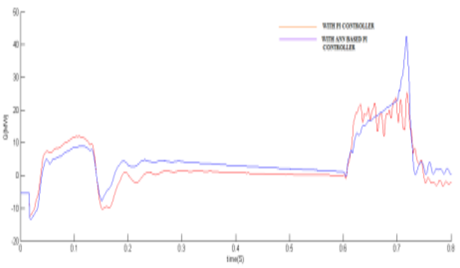


FIG.8 Comparison of Real and Reactive Power with PI and ANN based PI Controller during LLLG Fault.

Thus the real power is improved from 15 to 20 MW and reactive power are improved from 20 to 40 MW as shown in fig 8.The ripples are also reduced during LLLG fault when ANN controllers are implemented.

During the LLLG fault condition, the RSC control is switched to supply reactive current. The sinusoidal stator current is achieved with acceptable switching ripples even though the voltage injected by NSC on the neutral side of the stator winding is the PWM switching voltage. The GSC also switched to reactive current control mode during fault condition.

VI. CONCLUSION

Pulse Width Modulation Technique has become the most popular technique for the control of WECS. The inherent advantages of the nine

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switch inverter are its cost effectiveness and improved reliability. The simulation results reveal that the ANN based PI control fault-tolerant DFIG seamlessly rides through LLLG fault. The advantages and benefits associated with the proposed configuration over other FRT techniques are seamless Fault Ride Through, economical solution with only three additional switches, no need for output filter, series injection transformer and bypass switches.

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